IS 8161-2 (1986): Guide for equipment reliability testing, Part 2: Design of test cycles [LITD 2: Reliability of Electronic and Electrical Components and Equipment]

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Indian Standard

GUIDE FOR EQUIPMENT RELIABILITY TESTING

PART 2 DESIGN OF TEST CYCLES

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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Indian Standard

GUIDE FOR EQUIPMENT RELIABILITY TESTING

PART 2 DESIGN OF TEST CYCLES

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Indian Standard

GUIDE FOR EQUIPMENT RELIABILITY TESTING

PART 2 DESIGN OF TEST CYCLES

0. FOREWORD

0.1 This Indian Standard (Part 2) was adopted by the Indian Standards Institution on 14 October 1986, after the draft finalized by the Reliability of Electronics and Electrical Components and Equipment Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This standard which deals with the reliability requirements when these are expressed as a success ratio is the second in the series of Indian Standards for equipment reliability testing. To be able to write a detailed reliability test specification and perform a reliability test, the test engineer will need additional information which are dealt with in detail in other standards in this series. A list of standards envisaged in this series some of which are given on page 27.

0.3 This standard is largely based on IEC Document 56(CO) 106 Draft — Publication 605 'Equipment reliability testing : (Part 2) Guidance for the design of test cycles', issued by International Electrotechnical Commission (IEC).

1. SCOPE

1.1 This standard (Part 2) gives guidance for design of test cycles to evaluate reliability of electronic equipment.

2. TERMINOLOGY

2.0 For the purpose of this standard, the terms and definitions as given in IS : 1885 (Part 39)-1979* shall apply, in addition to the following.

2.1 Activity — State of equipment conditions and exposure to environment and usage.

*Electrotechnical vocabulary: Part 39 Reliability of electronic and electrical items (*first revision*).

2.2 Environmental Conditions — Physical and chemical conditions external to the equipment to which it is subjected at a certain time and comprising a combination of single environmental parameters and their severities.

2.3 Operating Conditions — Conditions related to the functioning of the equipment and comprising a combination of single operating parameters and their severities.

2.4 Parameter (Operating Environmental Parameter) — A chemical or physical quantity or combination of quantities defining the type of stress subjected to the equipment. Examples of operating parameters are load, power supply, etc, *see* **5.1**. Examples of environmental parameters are ambient temperature, vibration, etc, *see* **5.2**.

2.5 Severity (of Operating or Environmental Parameter) — A value of each quantity characterizing the operating or environmental parameter. The severity defines the stress level subjected to the equipment. Examples of severities are : 35 of power load, -10 percent voltage drop and $+2$ percent frequency deviation of power supply, $+70^\circ C$ of ambient temperature, 50 m/s^2 at 20-500 Hz of sinusoidal vibration.

2.6 Severity Class — Interval of severities between two stated limits inside the relevant severity range. Example of severity class: $+15^\circ C$ to $+35^\circ C$ of ambient temperature.

2.7 Test Severity — Severity of operating or environmental parameter applied to the item(s) during the testing.

2.8 Representative Severity — Test severity judged to give a failure rate approximating to the average failure rate over a severity class.

3. APPLICABILITY

3.1 This standard provides a general procedure for the design of test cycles, where no applicable preferred test cycles can be found in IS : 8161 (Part 3)*. It applies to the design of the operating and environmental test cycles referred to in IS : 8161 (Part 1)-1976†. The resulting test cycle should be included in the detailed reliability test specification.

3.2 Test cycles designed according to this standard are not intended to replace ordinary tests such as qualification tests, functional performance tests and environmental tests.

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*Guide for equipment reliability testing: Part 3 Preferred test conditions for equipment reliability testing.

†Guide for equipment reliability testing: Part 1 Principles and procedures.

3.3 The test cycle is a sequence of different operating and environmental test conditions which are based upon actual use conditions, as defined for example, by the relevant product specification. The equipment undergoing reliability testing is subjected to repeated test cycles. The number of cycles to be used will depend on the accumulated relevant test time, as required by the selected compliance test plan of IS : 8161 (Part 7)-1977* or as suitable for determination testing according to IS : 8161 (Part 4)-1985†.

3.4 The step-by-step procedure described here is intended for any specific equipment to be tested, when it is considered necessary to simulate closely the real use conditions of the equipment. It is applicable fully to laboratory testing. To field testing it may be applied mainly as far as operating conditions (including load, supply, etc) are concerned.

4. GENERAL ASPECTS OF TEST CONDITIONS IN RELATION TO USE CONDITIONS

4.1 Generally, a good correspondence between test and use reliability is desired. It is thus necessary that the test conditions are properly correlated to the conditions to which the equipment is subjected in real use. These conditions may, however, be very complex and not possible to reproduce in detail by the testing facilities. A proper correlation can therefore be achieved only if the influences of operating conditions, single and combined environments and sequences of environments are carefully examined and the most important factors are simulated by the reliability test conditions.

4.2 Calendar time compression by shortening periods of operating under low stress conditions, such as no load or idling, may be used in the testing. Accelerated testing by overstress conditions should normally be avoided [*see* IS : 8161 (Part 1)-1976‡].

4.3 In most cases, testing under constant conditions is not adequate for the purpose. A test cycle shall be designed giving an appropriate sequence of several different operating and environmental test conditions, some of them combined. For practical reasons the resulting test cycle generally will be only an approximation of the real use conditions.

4.4 The test cycle may be deliberately designed to provide a closer rougher approximation, corresponding to a higher or lower degree of simulation of the use conditions. A cycle with a high degree of simulation is more complex and is closer to the actual use conditions,

*Guide for equipment reliability testing: Part 7 Compliance test plans for failure rate and mean time between failures assuming constant failure.

†Guide for equipment reliability testing: Part 4 Procedure for determining estimates point and confidence limits from equipment reliability determination tests.

‡Guide for equipment reliability testing: Part 1 Principles and procedures.

but is also more costly to realize and to perform by practical testing. A high degree of simulation is recommended when the outcome of the test is crucial, for example, when failure consequences are critical in terms of safety and economic loss or in conflict with regulations, as with environmental pollution. Where failure consequences are less important, for example, in TV and radio for entertainment a low degree of simulation of use conditions may be used.

4.5 The procedure described here is intended mainly for a high degree of simulation. A low degree of simulation test cycle may be derived from a high degree of simulation cycle, but not *vice versa*. The same procedure may be used with lower precision to arrive directly at a low degree of simulation.

4.6 The principle followed in the procedure should result in a test cycle so designed that all important combinations of operating and environmental conditions appear during the test cycle with a relative part of equipment life. However, the technical feasibility and cost of generating the test conditions should be actively considered at every step.

5. DESCRIPTION OF THE USE CONDITIONS

5.0 The use conditions normally consist of a number of operating and environmental parameters appearing simultaneously or sequentially. Each of these parameters may have stress levels (severities) that could cause equipment failures.

5.1 Operating Conditions

5.1.1 Operating parameters to be considered are as follows:

[*see also* IS : 8161 (Part 1)-1976*]

a) Functional modes (non-operation is considered as one functional mode);

b) Input signals, data, or material to be processed;

c) Load conditions; output power level, static load, etc;

d) Actual manipulation by operator and serviceman; and

e) Supporting supplies; power, cooling, lubrication, etc.

5.1.2 The severities of the operating parameters determine the stresses imposed by operation.

5.2 Environmental Conditions

5.2.0 Environmental parameters of major interest are listed below. They are grouped into climatic, mechanical and other environmental parameters. The lists are not complete but can be used as check-lists covering the generally more important influences.

*Guide for equipment reliability testing: Part 1 Principles and procedures.

For all parameters the severities and the duration or number of occurrences have to be considered. The severities of the parameters of importance in the particular case shall be described in enough detail (for example, by the time distribution of severities) to make possible a transformation into suitable test severities as required in **6**.

5.2.1 *Climatic Environmental Parameters* — Some climatic parameters are listed in Table 1, covering both outdoor and indoor conditions. Some of them are closely interrelated and shall be considered together.

TABLE 1 CLIMATIC ENVIRONMENTAL PARAMETERS

Parameter (1)	Described by, for Example (2)
Ambient temperature Humidity	Climatogram
Rapid changes of temperature	Range, rate of change
Air pressure	Range
Precipitation	Type, rate
Wind	Velocity
Solar radiation	Intensity

5.2.2 *Mechanical Environmental Parameters* — Some mechanical parameters are presented in Table 2.

TABLE 2 MECHANICAL ENVIRONMENTAL PARAMETERS

Parameter (1)	Described by, for Example (2)
Shock	Shape, peak acceleration, duration, direction
Bump (repeated shocks)	Peak acceleration, direction
Drop and topple	Drop height, points of impact
Free fall	Fall height, attitude
Vibration	Waveform, frequency range, amplitude or acceleration density, direction
Steady acceleration	Acceleration values, direction

5.2.3 *Other Environmental Parameters* — In some cases consideration should be given to parameters such as:

a) Conducted or radiated electromagnetic interference, electrostatic discharges and lightning effects;

b) Atmospheric contamination with abrasive or corrosive effects, for example, dust, salt, industrial atmosphere;

c) Immersion in liquid, splashing, etc;

d) Nuclear radiation, X-ray radiation, etc; and

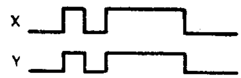
e) Biological agents, for example, fungus, insects.

5.3 Relationship of Operating and Environmental Parameters

5.3.1 When analyzing the use conditions in order to design test cycles, the relationship, if any, of the operating and environmental parameters shall be considered. Also certain severities of these parameters may have some kind of relationship. Any of the cases shown in Fig. 1 may occur.

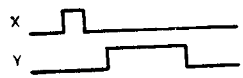
a) Mutually dependent parameters or severities:

Parameters or severities that always occur simultaneously, never separately. They may be treated as one combined parameter.



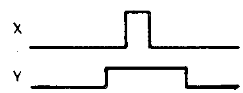
b) Mutually exclusive parameters or severities:

Parameters or severities that never occur simultaneously. They may, for example, occur in completely different phases or activities of use. Different severities of the same parameter are always mutually exclusive.



c) Dependent parameter or severity:

Parameter or severity that only occurs provided another parameter or severity is present. In the figure, severity *X* (for example, full operation) is dependent on severity *Y* (for example, power on).



d) Independent parameters or severities:

Parameters or severities that only occurs simultaneously by change. The probability of simultaneous occurrence is assumed to be proportional to the relative durations of each of the parameters or severities.

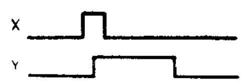


FIG. 1 RELATIONSHIPS

5.3.2 The figure investigation of parameters and severities relevant for testing the equipment will be discussed in 6. The relationship is of importance in order to find out which parameters and severities should be combined in the test cycle.

5.3.3 Another consideration in this respect is the degree of synergistic effects obtained by the combination or the sequence of two or more parameters. These effects depend on the degree in which possible failure mechanisms in the equipment are initiated and maintained by different parameters. When the synergistic effects are strong, the relevant parameters should be combined or maintained in the correct sequence in the test cycle. When they are negligible, the parameters may be unrelated in time in the test cycle.

6. PROCEDURE FOR THE DESIGN OF TEST CYCLES

6.0 A step-by-step procedure for arriving at a suitable reliability test cycle for a specific equipment to be tested is described in this clause. It is recommended that the steps be well documented. It will then be possible for the user of the equipment to compare the pre-requisites for the test cycle and the particular use conditions. Guidance for the contents of test cycle documentation is given in **7**.

6.0.1 The use conditions for individual items of equipment may vary with time over the relevant part of equipment life. The design of test cycles should always consider the durations and severities of the time sequences of use conditions. Where necessary, to take account of very different individual use conditions, separate test cycles may need to be designed for one and the same type of equipment.

6.0.2 The following outlines the step-by-step procedure. The steps may be followed in more detail in the work example in Appendix A. In cases where the use conditions are relatively simple, or where there is sufficient experience of applicable test cycles, a suitable test cycle may be arrived at without performing all steps in detail.

6.1 Step 1 — Division into Activities

6.1.1 The relevant part of equipment life is divided into distinct 'activities' to represent typical operating and/or environmental profiles. The purpose of this step is to break down the totality of use conditions into constituents which can be conveniently handled separately.

6.1.2 The duration of each activity should be determined in relation to the total time of the relevant part of equipment life. Together with other similar relative durations defined from use data in further steps, this ratio is used to determine relative durations in the test cycle.

6.2 Step 2 — Identification of Relevant Operating and Environmental Parameters and Their Relationship

6.2.1 The operating and environmental parameters associated with each activity are identified. The environmental parameters should be adapted as far as possible to standard tests included in IS : 9000* series. The tables in **5.1** and **5.2** can be used as check lists. Note that the tables do not include all specific parameters that may need to be considered.

6.2.2 Parameters of very little or no importance to the reliability of the equipment should be omitted. However, at this stage they should be included if there is any doubt. Separate short-term environmental tests may be adequate to demonstrate satisfactory resistance to certain environments, obviating the need for their inclusion in the reliability test.

*Basic environmental testing procedures for electronic and electrical items.

6.2.3 The duration of each important parameter or the number of occurrences (for example, of bumps) should be related to the duration of the activity by estimating the ratio or frequency of occurrence, as applicable.

6.2.4 The relationship of the parameters should be analyzed qualitatively and noted. The result is used as an input to Step 4.

6.3 Step 3 — Evaluation of Severities

6.3.1 The severities should be estimated for each operating and environmental parameter relevant to each activity. The range of expected severities for each parameter is divided into 'severity classes' (*see* Fig. 2).

6.3.2 Each serverity class should be such that it can be represented by one test severity, that is, representative severity. If possible, the representative severity should be a standard procedure or value. It is advisable to limit the number of classes in order to simplify the resulting test cycle.

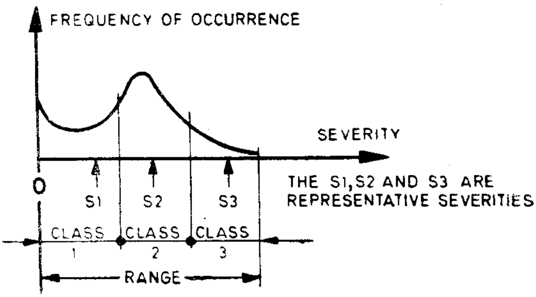


FIG. 2 EVALUATION OF SEVERITIES

6.4 Step 4 — Evaluation of Combinations

6.4.1 As mentioned in **5.3**, the relevant operating and environmental parameters often appear simultaneously. If so, these parameters should preferably be combined in the test cycle. When synergistic effects are suspected, they shall be combined, if at all technically and economically possible.

6.4.2 The relationship of parameters and severity classes of importance to the failure rate of the equipment should be evaluated, in order to have them adequately represented in the test cycle. The important combinations are stated and the duration of each combination estimated in relation to the duration of the activity.

6.4.3 The relative duration of combination shall be chosen with respect to the type of relationship. The examples in Fig. 3 may clarify the issue.

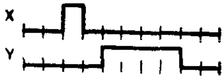
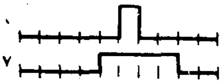
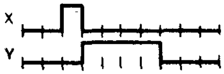
		Relative duration Param. X	Param. Y	Comb. X, Y
a) Mutually dependent:				
Parameter		0·5	0·5	0·5
b) Mutually exclusive:				
Parameter		0·1	0·4	0
c) Dependent, X dependent on Y:				
Parameter		0·1	0·4	0·1
d) Independent:				
Parameter		0·1	0·4	0·04

FIG. 3 EXAMPLES OF RELATIVE DURATIONS

6.4.4 General formulae for calculating the relative duration of combinations are shown below. The relative durations are designated $d(X)$ and $d(Y)$ for the single parameters X and Y, and $d(X, Y)$ for the combination of parameters X and Y:

a) Mutually dependent: $d(X, Y) = d(X) = d(Y)$

b) Mutually exclusive: $d(X, Y) = 0$

c) Dependent, X on Y: $d(X, Y) =$ Minimum $d(X), d(Y)$

d) Independent: $d(X, Y) = d(X) . d(Y)$

The relative time a parameter may appear separately in the test cycle is now the remaining relative duration:

$$d(X \text{ sep}) = d(X) - d(X, Y) - d(X, Z) \ldots$$

$$d(Y \text{ sep}) = d(Y) - d(X, Y) - d(Y, Z) \ldots$$

6.4.5 This may be calculated for the purpose of checking that the sum of relative durations equals 1. Less laborious, however, is to do this graphically as shown by the simple example in Step 7 on page 13. The work example in Appendix A shows the complete calculations including reductions for combinations.

6.4.6 When a frequency, f, rather than a duration is given for the parameter X, for example, 10 bumps per hour at the severity of 100 m/s^2, the number of occasions, $n(X, Y)$, is calculated for the combination:

$$n(X, Y) = f(X) . d(Y)$$

In the general case the relationship of any two or more parameters should be presented in a suitable matrix format. It may be possible to simplify the presentation by using a table of relative durations and frequencies (or number of occasions) with activities and environmental parameters vertically and operating parameters horizontally or *vice versa.*

6.5 Step 5 — Summation Overall Activities

6.5.1 For a systematic approach to the design of test cycles, it is useful to tabulate the contributions of the duration or frequency of each severity class (representative severity) from each activity. The summation table will provide quantitative data in establishing the test cycle.

6.5.2 In this summation, the contribution from each activity to the duration or frequency of a certain class is multiplied by the ratio t(activity)/t(total), whereby it is related to the total duration. The summation is simplified if the same definition of parameters and severity classes has been used for all the activities.

6.5.3 All severity classes of single and combined parameters should preferably be included in this step, the duration of single parameters being reduced in accordance with the extent to which they appear in the combinations.

6.5.4 In complicated cases it might be difficult to calculate the reduction of each factor due to all combinations. Even in simple cases it may be inconvenient. The duration or frequency of a certain severity class may instead be referred to its total appearance, single and in combinations, and a superposition made graphically when designing the final test cycle, Step 7. In such cases, however, the checks in the summation shall be altered accordingly and the total sum of 1 will be exceeded.

6.5.5 Step 5 results in a table similar to that of Step 4 except that it is completed with the remaining single parameters and not divided up into activities. The activities are now eliminated and do not appear further separately in the procedure, nor in the test cycle. It may be useful to split up Step 5 in two or more interim steps in complicated cases.

6.6 Step 6 — Critical Preview

6.6.1 Before proceeding to the design of a test cycle, the contents of the table of Step 5 should be reviewed and a reduction of environmental parameters and severity classes made where such omissions certainly can be expected not to effect the failure rate to an important extent. Particular attention should be paid to environmental parameters and combined environments which will be costly and difficult to generate during the reliability testing.

6.6.2 At this step, also the appropriate sequence for the parameters, severity classes and combinations in the test cycle should be considered. Pairs and groups of conditions that give additional effects when taken in close sequence (especially humidity followed by cold) should be noted.

A revised table is then constructed.

6.7 Step 7 — Detailed Design of the Test Cycle

6.7.1 The revised table of Step 6 forms the basis for the design of the reliability test cycle. A suitable length of the test cycle should be determined, taking into account:

a) The cycle should be long enough to make the testing practicable. This is often determined by the smallest value of the relative durations in the table obtained in Step 6.

b) In case of time based tests, the test cycle should be short enough to comply with IS : 8161 (Part 1)-1976*.

6.7.2 All relative durations are then transformed into durations for one cycle through multiplication by the length of the cycle. Rounding off is made to complete cycles, number of bumps, etc.

6.7.3 The test cycle should then be designed and reviewed. It may be necessary to introduce combinations which have not been included in the tables in order to achieve the suitable length of the test cycle. Any simplifications necessary to make the testing technically and economically feasible should be made. The test cycle shall allow for the preventive maintenance programme to be applied during the testing by suitable points indicated in the cycle where interruption for maintenance may be made. The points in the test cycle at which monitoring by intervals of the test item performance shall be done shall also be indicated.

6.7.4 If there are portions of the test cycle where resumption of the testing of a failed test item is not recommended, these portions should be indicated. IS : 8161 (Part 1)-1976* calls for resumption at the point of interruption if not otherwise specified.

*Guide for equipment reliability testing: Part 1 Principles and procedures.

6.7.5 The resulting test cycle should be presented in a diagram as shown by the simple example in Fig. 4 and the more complex one in Appendix A. It should be included in the detailed reliability test specification.

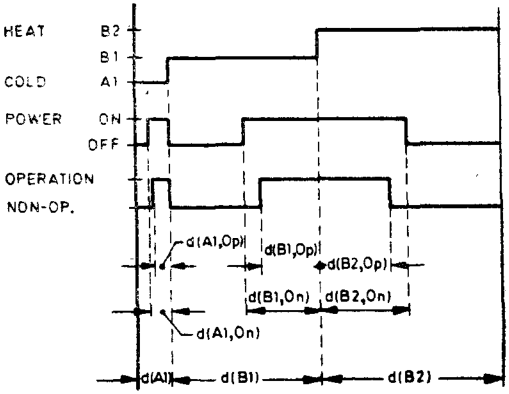
a) Relevant parameters and their relationships:

Environmental:	Cold, Heat	Mutually exclusive	Independent
Operating:	Power Supply, Operation	Dependent, Operation only at Power on	

b) Relative durations:

Cold, severity	*A1**	0·1	1·0
Heat, severity	*B1**	0·4	
	*B2**	0·5	
Power supply	*On**	0·5	
Operation	*Op**	0·4	

The diagram of the sest cycle below is drawn to scale.



$$d\,(A1,\,Op) = d\,(A1)\;.\;d\,(Op) = 0{\cdot}04$$
$$d\,(B1,\,Op) = d\,(B1)\;.\;d\,(Op) = 0{\cdot}16$$
$$d\,(B2,\,Op) = d\,(B2)\;.\;d\,(Op) = 0{\cdot}20$$
$$d\,(A1,\,On) = d\,(A1)\;.\;d\,(On) = 0{\cdot}05$$
$$d\,(B1,\,On) = d\,(B1)\;.\;d\,(On) = 0{\cdot}20$$
$$d\,(B2,\,On) = d\,(B2)\;.\;d\,(On) = 0{\cdot}25$$

*These symbols are defined in Table 5.

FIG. 4 SIMPLE TEST CYCLE

7. SUMMARY OF DOCUMENTATION OF A RELIABILITY TEST CYCLE

7.1 The documentation should give enough information about the prerequisites in order to enable the prospective user of the equipment to judge if the cycle sufficiently covers the application of the specific equipment to be tested. It should also be detailed enough to enable the test laboratory to realize the test cycle in practice with the necessary reproducibility.

7.2 The following heading and contents are recommended as far as they are relevant:

a) *Applicability* — Descriptive definition of the application(s) on which the test cycle is based. The definition shall be clear and detailed enough.

b) *Degree of simulation* — Brief statement in case there are other test cycles intended to cover the same application.

c) *Relevant part of equipment life* — Description of the activities covered by the test cycle. In some cases excluded activities should be pointed out.

d) *Basic assumptions underlying the severities* — Statement of the assumptions and reference to the sources of information used to arrive at the severities given in the test cycle. Parameters of special importance and parameters that are neglected, as well as any limitations of severity ranges, should be noted. Basic relative durations and relationships used for the design of the test cycle should be listed.

e) *Description of the test cycle* — Detailed description of each time period and severity of the test cycle, with appropriate references to the standardized tests of IS : 9000 series.

f) *Comments on simplifications* — If simplifications are made in the final design of the test cycle (Step 7), these should be described and possible effects on applicability and basic assumptions pointed out.

g) *Diagram of the test cycle* — Graphical presentation giving a survey of the test cycle.

APPENDIX A

(*Clauses* 6.0.2, 6.4.5 *and* 6.7.5)

DETAILED WORK EXAMPLE

A-0. The steps of the procedure described in **5** of this standard are applied to the following example which is based on data typical for this case. It is included only as an aid for checking the correct understanding of the procedure. It requires, however, a certain amount of calculation work.

A-0.1 The result from the example should not be regarded as a standard test cycle. Preferred test conditions and standard test cycles are detailed in IS : 8161 (Part 3)*.

A-0.2 Basic conditions for the example:

a) Equipment	Portable battery-operated sound level meter.
b) Application	For measurements outdoors, indoors, inland vehicles and ships, operating while not being carried by hand. Surface transport from place to place while in 'off' condition.
c) Climate zone	Cold temperate.
d) Relevant part of equipment life	From taking the equipment out from the instrument store until it is put back again, repeatedly.
e) Degree of simulation	High.

A-1. STEP 1 DIVISION INTO ACTIVITIES

A-1.1 The relevant part, t(total), of equipment life is divided into activities with regard to typical operating and environmental profiles. The duration of the activity is designated t(activity). The relative durations, d(activity) = t(activity)/t(total), are determined (*see* Table 3).

A-2. STEP 2 IDENTIFICATION OF RELEVANT OPERATING AND ENVIRONMENTAL PARAMETERS

A-2.1 Relevant operating and environmental parameters of importance to the reliability of the sound level meter are identified.

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*Guide for equipment reliability testing: Part 3 Preferred test conditions for equipment reliability testing.

TABLE 3 ACTIVITIES

(*Clause* A-1.1)

Activity	Description of Activity	Relative Duration	
(1)	(2)	(3)	(4)
1.	Transportation from store to place for measurements, setting up. Moving of sound level meter to other measuring points. Dismounting and transportation back to store	0·3	$d(1)$
2.	Stationary use at locations outdoors and indoors*	0·6	$d(2)$
3.	Use on board land vehicles (cars, trucks, railway carriages, etc) and ships*	0·1	$d(3)$
		1·0	

*Including all the time when the sound level meter is set up for measurements.

A-2.2 The relative durations of the parameters in each activity are determined: d(parameter) = t(parameter)/t(activity). For parameters involving transients, instead, the frequency during each activity is determined (*see* Table 4).

TABLE 4 OPERATING AND ENVIRONMENTAL PARAMETERS

Parameter	Relative Duration or Frequency		
	Activity 1	Activity 2	Activity 3
(1)	(2)	(3)	(4)
Functional mode*: Measuring, stand-by and battery off	1	1	1
Temperature: Cold and heat	1	1	1
Change of temperature, with high rate of change, > 1°C/min	0·02/h	0	0
Humidity: Damp heat > 65% RH, > 15°C	0·2	0·1	0·01
Bump: 10 m/s² peak	10/h	0	20/h
Free fall: > 5 mm	0·1/h	0	0
Vibration: > 1 mm or > 5 m/s² (rms)	0·2	0	0·3

*Power supply from the battery is on in the measuring and stand-by modes.

A-2.3 The relationships are noted:

a) Functional modes:

i) Measuring	Excluded at battery off and stand-by, otherwise independent.
ii) Stand-by	Excluded at battery off and measuring, otherwise independent.
iii) Battery off	Excluded at measuring and stand-by, otherwise independent.
b) Temperature	Independent of other parameters.
c) Temperature change	Independent of other parameters.
d) Humidity	Excluded at temp $< 15°C$, otherwise independent.
e) Bump	Excluded at vibration and free fall, otherwise independent.
f) Free fall	Dependent on battery off, excluded at vibration and bump, otherwise independent.
g) Vibration	Excluded at bump and free fall, otherwise independent.

A-3. STEP 3 EVALUATION OF SEVERITIES

A-3.1 The severities of the operating and environmental parameters are analyzed using available data. The relative durations and frequencies of the severity classes in each activity are determined:

$$d(\text{ class }) = t(\text{ class })/t(\text{activity })$$

A-3.2 A master table is then drawn up, *see* Table 5.

A-4. STEP 4 EVALUATION OF COMBINATIONS

A-4.1 The relationships of parameters and severity classes are evaluated and the result tabulated. In this case all operating conditions are mutually exclusive. Therefore, it is sufficient to tabulate operating parameters against important combinations of environmental parameters (*see* Table 6).

A-4.2 Reasons for Deletion of Certain Combinations:

a) *Activity 1*

Heat, Bump:	The effects considered much less than from Cold, Bump
Temp, Fall:	Covered by Cold, Bump
Cold, Vib:	Covered by Cold, Bump
Heat, Vib:	Covered by Activity 3

b) *Activity 2*

Effects of combinations with humidity considered negligible

c) *Activity 3*

Bump and Vib combination with (*B2*, *Boff*) are not regarded as important combinations and their relative frequencies and durations transferred to *B1* (not shown in this table)

A-4.3 The relative duration or frequency of each combination in each activity is determined:

$$d(\text{ comb }) = t(\text{ comb })/t(\text{ activity })$$

A-5. STEP 5 SUMMATION OVERALL ACTIVITIES

A-5.1 The summation is facilitated by an interim step for reduction of single parameter durations as shown in Table 7.

A-5.2 A complete table containing the summations overall activities of the frequencies and durations of each severity class and combination is now worked out (*see* Table 8).

A-6. STEP 6 CRITICAL REVIEW

A-6.1 The combination of humidity and battery on conditions is considered an unnecessary complication. The (*C*, Measuring) and (*C*, Stand-by) durations are deleted and the (*C*, Battery off) increased accordingly. Due corrections are made of the *B1* durations.

A-6.2 The duration of *D* is very small. The effect of temperature change with high ambient humidity can be obtained by the heating up and cooling off in the *C3* humidity conditions. *D* is therefore deleted and the duration of *C3* increased accordingly. The effect of rapid change of temperature is obtained by introducing a prescribed time of transition between *B1* and *A1*, corresponding to test Na.

A-6.3 Humidity *C3* and cold *A1* are put in close sequence for the effect of internal icing.

TABLE 5 MASTER TABLE

(*Clause* A-3.2)

Activity and Parameter	Operating and Environmental Severity Class: Severity Class	Representative Severity	Symbol*	Relative Duration or Frequency	Sum[1])
(1)	(2)	(3)	(4)	(5)	(6)
Activity 1					
Functional mode		Measuring	*Me*	0	
		Stand-by	*Sb*	0	
		Battery off	*Boff*	1	1·0
Temperature	−35°C to −5°C	−25°C	*A1*	0·04	
	−5°C to +15°C	+5°C	*A2*	0·06	
	+15°C to +35°C	+25°C	*B1*	0·83	
	+55°C to +65°C	+55°C	*B2*	0·07	1·0
Change of temp	Temp diff <50°C	−25, +25°C	*N*	0·02/h	0·02/h
Humidity					
1. Steady state (with constant temp)	<85% RH +15 to +45°C	80%, +25°C[2])	*C1*	0·135	
	>85% RH +15 to +30°C	95%, +25°C	*C2*	0·050	
	>85% RH +30 to +45°C	95%, +40°C	*C3*	0·013	
2. Cyclic (with cyclic temp changes)	>90% RH +15 to +40°C >0·3°C/min	95%, +25 to +40°C	*D*	0·002	0·2
Bump	equivalent half sine				
	1 g_n to 12 g_n, 16 ms	10 g_n, 16 ms	*Eb1*	9/h	
	12 g_n to 30 g_n, 6 ms	25 g_n, 6 ms	*Eb2*	1/h	10/h
Free fall	5 mm to 30 mm	25 mm	*Ed1*	0·09/h	
	30 mm to 55 mm	50 mm	*Ed2*	0·01/h	0·1/h
Vibration	Equivalent sinusoidal 10 − 150 Hz				
	<4 mm 1 g_n	3·5 mm or 1 g_n	*F1*	0·15	
	4 mm or 1 g_n − 8 mm or	7·5 mm or 2 g_n	*F2*	0·05	0·2

Activity 2	2 g_n				
Function mode		Measuring	*Me*	0·35	
		Stand-by	*Sb*	0·35	
		Battery off	*Boff*	0·3	1·0
Temperature	−35°C to −5°C	−25°C	*A1*	0·02	
	−5°C to +15°C	+5°C	*A2*	0·03	
	+15°C to +35°C	+25°C	*B1*	0·92	
	+35°C to +65°C	+55°C	*B2*	0·03	1·0
Humidity					
1. Steady state (with constant temp)	<85% RH +15 to +45°C	80%, +25°C	*C1*	0·07	
	>85% RH +15 to +30°C	95%, +25°C	*C2*	0·02	
	>85% RH +30 to +45°C	95%, +40°C	*C3*	0·01	
2. Cyclic (with cyclic temp changes)	>90% RH +15 to +40°C >0·3°C/min	95%, +25 to +40°C	*D*	0·001	0·1[3])
Activity 3					
Functional mode		Measuring	*Me*	0·40	
		Stand-by	*Sb*	0·35	
		Battery off	*Boff*	0·25	1·0
Temperature	−5°C +15°C	+5°C	*A2*	0·05	
	+15°C to +35°C	+25°C	*B1*	0·85	
	+35°C to +65°C	+55°C	*B2*	0·10	1·0
Humidity[4])					
Bump	equivalent half sine				
	1 g_n to 12 g_n, 16 ms	10 g_n, 16 ms	*Eb1*	18/h	
	12 g_n to 30 g_n, 6 ms	25 g_n, 6 ms	*Eb2*	2/h	20/h
Vibration	equivalant sinusoidal 10 − 150 Hz				
	< 4 mm 1 g_n	3·5 mm or 1 g_n	*F1*	0·2	
	4 mm or 1 g_n − 8 mm or 2 g_n	7·5 mm or 2 g_n	*F2*	0·1	0·3

(Continued)

TABLE 5 MASTER TABLE — *Contd*

*These symbols are used for the purpose of this standard for mathematical expression used to define their relationships.

1) Equals the figures for each activity and parameter of Table 4.

2) The distribution of temperatures is such that the range + 15°C to + 35°C dominates very strongly, which justifies the temperature + 25°C denoted.

3) The difference of 0·001 can be neglected.

4) The relative humidity and temperature changes are normally lower than those applied in Activity 2, which includes outdoor use. Since, furthermore, the duration of Activity 3 is much shorter than that of Activity 2, there are enough reasons to neglect the influence of humidity for Activity 3.

TABLE 6 EVALUATION OF COMBINATIONS

(*Clause* A-4.1)

Activity Environmental Parameter	Symbol (Same as in Table 5)	Relative Duration $d(X)$ or Frequency $f(X)$			
		Functional Mode			Total for All Modes
		Measuring	Stand-by	Battery off	
(1)	(2)	(3)	(4)	(5)	(6)
Activity 1					
Bump, cold	*Eb1*, *A1*	0	0	0·36/h[1])	0·36/h
	Eb2, *A1*	0	0	0·04/h[2])	0·04/h
Activity 2					
Temperature	*A1*	0·007[3])	0·007	0·006	0·02
	A2	0·010	0·011	0·009	0·03
	B1	0·322	0·322	0·276[4])	0·92
	B2	0·010	0·011	0·009	0·03
Humidity, temp	*C1*, *B1*[5])	0·025[6])	0·024	0·021	0·07
	C2, *B1*	0·007	0·007	0·006	0·02
	C3, *B1*[7])	0·004	0·003	0·003	0·01
	C	—	—	0·001[8])	0·001
Activity 3					
Temperature	*A2*	0·020	0·018	0·012	0·05
	B1	0·340	0·298	0·212	0·85
	B2	0·040	0·035	0·025	0·10
Bump, heat	*Eb1*, *B2*	0·72/h[9])	0·63/h	—	—
	Eb2, *B2*	0·08/h	0·07/h	—	—
Vib, heat	*F1*, *B2*	0·008	0·007	—	—
	F2, *B2*	0·004	0·004	—	—

In the notes below the first figure inside the brackets is the activity number.

1) $f(1, Eb1) \cdot d(1, A1) \cdot d(1, Boff) = f(1, Eb1, A1, Boff)$; 9/h . 0·04 . 1 = 0·36/h

2) $f(1, Eb2) \cdot d(1, A1) \cdot d(1, Boff)$

3) $d(2, A1) \cdot d(2, Me)$

4) $d(2, B1) \cdot d(2, Boff)$

5) The temperature intervals of *C1* and *B1* are not identical, as they are chosen with regard to the damp heat and dry heat tests, respectively. The temperatures everities are, however, the same and the *C1* duration can therefore be taken from the *B1* duration.

6) $d(2, C1) \cdot d(2, Me)$

7) The temperature intervals of *C3* and *B1* differ considerably. But, in respect to the high temperature of *B2* (+55°C), it is considered better to take the 0·001 of *C3* from the 0·92 of *B1* rather than from the 0·03 of *B2*.

8) Humidity with temperature changes is important only with no internal heating (Battery off). In accordance with Note 7), the *B1 Boff* 0·276 should be reduced by 0·001. This reduction is, however, small enough to be neglected.

9) $f(3, Eb1) \cdot d(3, B2) \cdot d(3, Me)$

TABLE 7 SUMMATION OF TEMPERATURE

(*Clause* A-5.1)

Activity Environmental Parameter	Symbol (Same as in Table 5)	Relative Duration or Frequency			
		Functional Modes			
		Measuring	Stand-by	Battery off	Total for All Modes
(1)	(2)	(3)	(4)	(5)	(6)
Activity 2					
Temperature	*A1*	0·007	0·007	0·006	0·02
	A2	0·010	0·011	0·009	0·03
	B1	0·287[1)]	0·287	0·276	0·85
	B2	0·010	0·011	0·009	0·03

[1)] $d(2, B1, Me) - d(2, Me) . (d(2, C1) + d(2, C2) + d(2, C3))$

NOTE — If temperature had been limited to cold and dry heat in this example, the parameter temperature in Table 4 should have been 0·9 instead of 1·0 and no reduction made here in Step 5.

A-6.4 For practical reasons, the vibration and bump conditions are put in the sequence (*F, B1*), (*F, B2*), (*Eb, B2*), (*Eb, B1*), (*Eb, A1*), whereby mounting and dismounting of the test items are minimized.

A-7. STEP 7 DESIGN OF RELIABILITY TEST CYCLE

A-7.1 The final relative durations and frequencies are multiplied by the length of the cycle. In this case a suitable length was chosen to be 1 week = 168 h. Suitable points of time for functional check are specified. Deliberately, no functional checks are included on days 6 and 7 (Saturday and Sunday).

A-7.2 The final test cycle is listed by hours and presented graphically. The complete diagram is shown in Fig. 5. Example (the sound level meter): (Not to be regarded as standard test cycle).

A-7.3 In order to be complete, a detailed description of the test procedures and severities, with references to applicable standard tests, is necessary in addition to the diagram.

TABLE 8 SUMMATION OF ALL ACTIVITIES

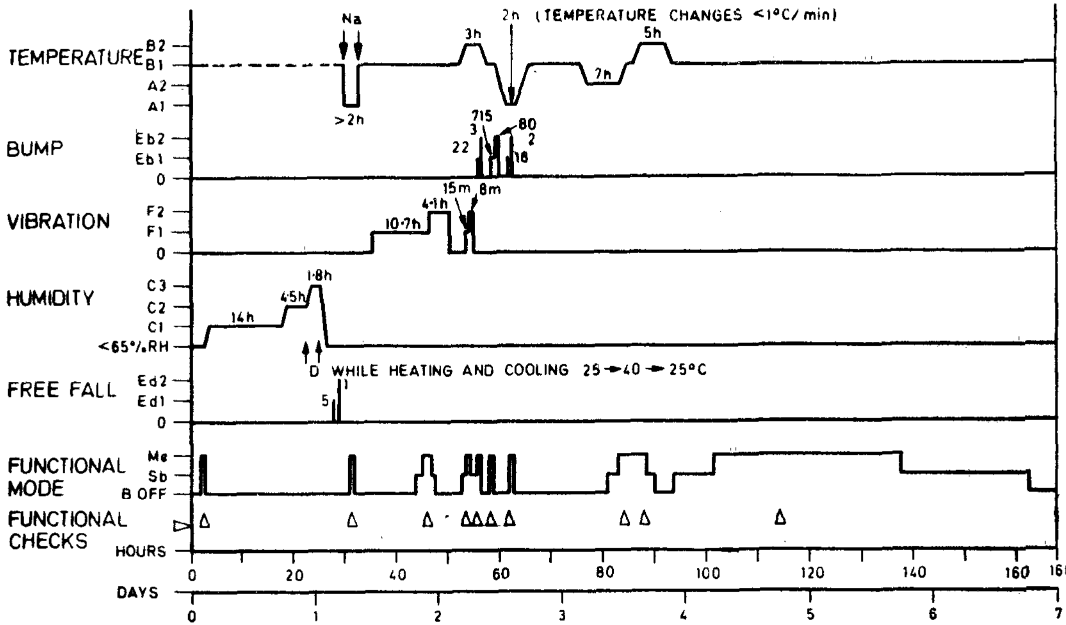
(*Clause* A-5.2)

Environmental Parameter	Symbol (Same as in Table 5)	Relative Duration or Frequency			
		Functional Modes			Total for All Modes
		Measuring	Stand-by	Battery off	
(1)	(2)	(3)	(4)	(5)	(6)
Temperature	*A1*	0·004	0·004	0·016[1])	0·024
	A2	0·008	0·008	0·025	0·041
	B1	0·194	0·193	0·291[2])	0·678
	B2	0·009	0·009	0·029	0·047
Change of temp	*N*	0	0	0·006/h	0·006/h
Humidity, temp	*C1*	0·015	0·014	0·053	0·082
	C2	0·004	0·004	0·019	0·027
	C3	0·002	0·002	0·006	0·010
	D	0	0	0·001	0·001
Bump, cold	*Eb1, A1*	0	0	0·108/h	0·108/h [3])
	Eb2, A1	0	0	0·012/h	0·012/h [3])
Bump, heat	*Eb1, B2*	0·072/h	0·063/h	0	0·135/h [3])
	Eb2, B2	0·008/h	0·007/h	0	0·015/h [3])
Bump	*Eb1*	0·648/h	0·567	3·042/h	4·257/h [3])
	Eb2	0·072/h	0·063	0·338/h	0·473/h [3])
Free fall	*Ed1*	0	0	0·027/h	0·027/h
	Ed2	0	0	0·003/h	0·003/h
Vib, heat	*F1, B2*	0·000 8	0·000 7	0	0·001 5
	F2, B2	0·000 4	0·000 4	0	0·000 8
	F1, B1	0·007 2	0·006 3	0·050 0	0·063 5
	F2, B1	0·003 6	0·003 1	0·017 5	0·024 2
					1·000

1) $d(1, A1) \cdot d(1, Boff) \cdot d(1) + d(2, A1, Boff) \cdot d(2)$

2) $[d(1, B1) - (d(1, C1) + d(1, C2) + d(1, C3) + d(1, D) + (d1, F1) + d(1, F2)] \cdot d(1, Boff) \cdot d(1) + (d(2, B1, Boff) \cdot d(2) + [d(3, B1, Boff) - ((d(3, F1) + d(3, F2))) \cdot d(3, Boff) - (d(3, F1, B2, Boff) + d(3, F2, B2, Boff)))] \cdot d(3)$

3) The table is checked by summing the durations or frequencies of the parameters and comparing with Tables 3 and 4, for example, parameter *Eb* sum 5·0/h = (0·3 . 10 + 0·1 . 20)/h.



EXAMPLE (THE SOUND LEVEL METER): NOT TO BE REGARDED AS A STANDARD TEST CYCLE.

FIG. 5 DIAGRAM OF FINAL TEST CYCLE

INDIAN STANDARDS

ON

EQUIPMENT RELIABILITY TESTING

IS : 8161 Guide for equipment reliability testing:

(Part 1)-1976 Principles and procedures

(Part 2) Design for test cycles (*under print*)

(Part 3) Preferred test conditions for equipment reliability testing:

Section 1 Indoor portable equipment (low degree of simulation) (*under print*)

Section 2 Equipment for stationary use in weather protected locations (high degree of simulation) (*under print*)

(Part 4)-1985 Procedure for determining point estimates and confidence limits from equipment reliability determination tests (*under print*)

(Part 5)-1981 Compliance test plans for success ratio

(Part 6)-1983 Tests for validity of a constant failure rate assumption

Section 2 Kolmogorov Simirnov test (*under print*)

Section 3 Bartlett's test (*under consideration*)

(Part 7)-1977 Compliance test plans for failure rate and mean time between failures assuming constant failure rate (*under consideration*)

(Part 8) Tests for the validity of a non-constant failure rate assumption (*under consideration*)

(Part 9) Compliance test plans assuming Weibull distribution of times to failure (*under consideration*)

(Part 10) Compliance test plans assuming normal distribution of times to failure (*under consideration*)

(Part 11)-1983 Flow chart describing preparations for the execution of reliability tests (*under consideration*)

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	Unit	Symbol	Definition
Force	newton	N	$1\ N = 1\ kg.m/s^2$
Energy	joule	J	$1\ J = 1\ N.m$
Power	watt	W	$1\ W = 1\ J/s$
Flux	weber	Wb	$1\ Wb = 1\ V.s$
Flux density	tesla	T	$1\ T = 1\ Wb/m^2$
Frequency	hertz	Hz	$1\ Hz = 1\ c/s\ (s^{-1})$
Electric conductance	siemens	S	$1\ S = 1\ A/V$
Electromotive force	volt	V	$1\ V = 1\ W/A$
Pressure, stress	pascal	Pa	$1\ Pa = 1\ N/m^2$

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